7. Natural Attenuation of Inorganics/Metals

ACID LEACH POND CLOSURE VIA DEMONSTRATED NATURAL ATTENUATION
Anderson, J.; A. Davis (Geomega, Boulder, CO); C. Burns (BHP Copper Co., Ely, NV)
Fifth International Conference on Acid Rock Drainage, 20-26 May 2000, Denver, CO
Society for Mining, Metallurgy, and Exploration, Inc. (SME), Littleton, CO. ISBN: 0-87335-182-7. Vol 1, p 733-742, ©2000

A closure plan was developed for the Intera Pond Facility, a former acid leaching collection pond at the BHP Robinson Mining Operations. To properly close the Intera Pond Facility, an engineering plan that was both technical and cost effective was developed. A primary objective of this closure project was to demonstrate to state regulators that following the proposed plan would minimize further degradation of water resources. Field data demonstrated natural attenuation of metal enriched solutes via carbonate reactions. Prospective fate and transport modeling indicated that it would not continue to degrade waters of the State.

NATURAL ATTENUATION OF METALS AND RADIONUCLIDES: REPORT FROM A WORKSHOP HELD BY SANDIA NATIONAL LABORATORIES
Brady, P.V.; DJ. Borns
Sandia National Labs., Albuquerque, NM. Geochemistry Dept.
Workshop on Natural Attenuation of Metals and Radionuclides, 18-20 June 1997, Albuquerque, NM
Report No: SAND-97-2727. NTIS: DE98001672. 250 pp, Nov 1997

Natural attenuation is increasingly applied to remediate contaminated soils and ground waters. Roughly 25% of Superfund groundwater remedies in 1995 involved some type of monitored natural attenuation, compared to almost none five years ago. Remediation by natural attenuation (RNA) requires clear evidence that contaminant levels are decreasing sufficiently over time, a defensible explanation of the attenuation mechanism, long-term monitoring, and a contingency plan at the very least. Although the primary focus of implementation has to date been the biodegradation of organic contaminants, there is a wealth of scientific evidence that natural processes reduce the bioavailability of contaminant metals and radionuclides. Natural attenuation of metals and radionuclides is likely to revolve around sorption, solubility, biologic uptake and dilution controls over contaminant availability. Some of these processes can be applied to actively remediate sites. Others, such as phytoremediation, are likely to be ineffective. RNA of metals and radionuclides is likely to require specialized site characterization to construct contaminant and site-specific conceptual models of contaminant behavior. Ideally, conceptual models should be refined such that contaminant attenuation can be confidently predicted into the future. The technical approach to RNA of metals and radionuclides is explored here. The full text of the report is available through the DOE Information Bridge: http://home.osti.gov/bridge/home.html

USE OF MULTI-PARAMETER SENSITIVITY ANALYSIS TO DETERMINE RELATIVE IMPORTANCE OF FACTORS INFLUENCING NATURAL ATTENUATION OF MINING CONTAMINANTS

Choi, J.Y.; J.W. Harvey; M.H. Conklin

U.S. Geological Survey Toxic Substances Hydrology Program: Proceedings of the Technical Meeting, 8-12 March 1999, Charleston, South Carolina. Volume 1: Contamination From Hard-Rock Mining
U.S. Geological Survey Water-Resources Investigation Report 99-4018A, p 185-192, 1999

Combining multi-Parametric Sensitivity Analysis (MPSA) with stream transport modeling is proposed to determine the relative importance of physical and biogeochemical processes controlling natural attenuation of contaminants. The MPSA is based on a large number of Monte-Carlo simulations to identify the sensitive parameters over a broad range of each parameter. This combined approach is applied to the transport of a mining contaminant, dissolved manganese in Pinal Creek basin, Arizona. The MPSA results show that transport of dissolved Mn(II) in Pinal Creek is controlled mainly by ground-water inflow, resulting spatial variation of pH in stream water, and the effect of pH on microbially mediated Mn(II) oxidation in the hyporheic zone. More Info: http://toxics.usgs.gov/pubs/wri99-4018/Volume1/index.html

MINIMIZE ARSENIC MOBILITY IN CONTAMINATED SOIL AS A NATURAL ATTENUATION APPROACH

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International Conference on Heavy Metals in the Environment, 6-10 August 2000, Ann Arbor, MI
Elsevier Science Publishers, Oxford, UK

Procedures are tested to estimate actual and potential arsenic release from soils on former infiltration fields and tannery sludge by batch extraction techniques and column leaching tests. Leachate concentrations obtained from both techniques are similar. Potentially mobile arsenic in iron oxide rich substrates can be assessed by time dependent dissolution in ascorbic acid. Arsenic mobility increases with pH and can be reduced by additions of calcium to an extent that leachate concentrations are limited to regulatory values. Arsenic is well retained in a calcite matrix under non-saturated conditions while in the water saturated zone permanent leaching of arsenic is observed. For arsenic, there is no natural attenuation per se. If no action is taken arsenic exceeds concentration limits in the soil leachate and groundwater. To view papers/abstracts from the conference: http://www.sph.umich.edu/eih/heavymetals/TechnicalProgram.html

SEASONAL INFLUENCES ON HEAVY METAL ATTENUATION IN AN ANAEROBIC TREATMENT WETLAND, BUTTE, MONTANA

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Society for Mining, Metallurgy, and Exploration, Inc. (SME), Littleton, CO. ISBN: 0-87335-182-7. Vol 2, p 1159-1168, ©2000

A demonstration scale, subsurface flow, anaerobic wetland was built to treat zinc and other metals in surface drainage near the historic mining center of Butte, MT. Based on three years of continuous monitoring (1996-1998), copper and cadmium were effectively removed year-round, but attenuation of dissolved zinc was dependent on hydraulic residence time (HRT) and bacterial sulfate reduction (BSR) rates. BSR rates decreased in winter months, as did HRT due to the development of thick frost zones in the

substrates. An additional problem was the inability of the wetland substrate to completely filter out fine-grained particles of ZnS forming in the anaerobic cells.

ENHANCED REMOVAL OF DISSOLVED MANGANESE IN HYPORHEIC ZONES: CENTIMETER-SCALE CAUSES AND KILOMETER- SCALE CONSEQUENCES
Harvey, J.W.; C.C. Fuller; M.H. Conklin
U.S. Geological Survey Toxic Substances Hydrology Program: Proceedings of the Technical Meeting, 8-12 March 1999, Charleston, South Carolina. Volume 1: Contamination From Hard-Rock Mining
U.S. Geological Survey Water-Resources Investigation Report 99-4018A, p 193-200, 1999

Characterizing both the causes and consequences of enhanced oxidation of dissolved manganese (Mn) in the hyporheic zone required measurements with spatial resolution varying across five orders of magnitude. Our measurements at Pinal Creek basin, AZ, ranged in scale from that of the fundamental interactions between surface and ground water (centimeters) to the scale of the perennial stream that receives ground-water discharge from the entire drainage basin (kilometers). Mean rate constants for the removal of dissolved manganese agreed closely between three scales of resolution in the field, ranging from centimeter-scale field measurements acquired in situ in hyporheic zones to kilometer-scale estimates determined using stream tracers. The laboratory estimate of the Mn removal-rate constant was approximately 30% lower than field estimates. In situ and laboratory rate constants had relatively large coefficients of variation (107% and 84%, respectively), which may be too large to be used reliably in transport simulations. Stream-tracer experiments provided estimates of the rate constant with lower uncertainties; 56% when averaged at the reach-scale (approximately 500 meters) and 26% when averaged at the basin-scale (3 kilometers). Because of the lower uncertainties the stream-tracer approach appeared to provide the most reliable basin-scale simulation of the effects of enhanced Mn-removal in hyporheic zones. The stream-tracer characterization alone, however, could not determine that removal of manganese was pH-dependent, or even that the reaction occurred in hyporheic zones (as opposed to slow-moving zones in surface water). Laboratory and in situ measurements within hyporheic zones provided the crucial evidence to support interpretations about the causal processes. Our experience at Pinal Creek basin leads us to conclude that a multi-scale approach is a necessity for characterizing enhanced biogeochemical reactions in hyporheic zones. More Info: http://toxics.usgs.gov/pubs/wri99-4018/Volume1/index.html

LEACHING AND ATTENUATION CHARACTERISTICS OF UNALTERED AND THERMALLY ALTERED MATERIALS FROM THE ROCKY MOUNTAIN 1 UNDERGROUND COAL GASIFICATION FIELD SITE
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Sponsored by Gas Research Inst., Chicago, IL, and Federal Energy Technol. Ctr., Morgantown, WV
NTIS: PB2000-106265. 106 pp, Feb 1998

This report reviews the results of an experimental leaching and attenuation investigation involving unaltered and thermally altered geological materials from the Rocky Mountain 1 (RM1) underground coal gasification (UCG) field test site near Hanna, Wyoming. Short- and long-term leaching experiments revealed that the potential for a variety of inorganics to be introduced into grounddwater by leaching from thermally altered geological materials at the RM1 site was very limited and that significant water quality impacts involving those inorganics were unlikely. At the same time, the attenuation experiments indicated

that both unaltered and thermally altered RM1 materials had notable capabilities to mediate the removal of a variety of trace elements, particularly heavy metals, from groundwater. A comparison of the experimental results with the groundwater chemistry data collected from the RM1 site suggested that laboratory-based leaching and attenuation activities utilizing site-specific conditions and materials have some predictive value. Furthermore, the results proved valuable for contributing to an understanding of the source, transport, and fate of inorganics, including a number of potentially problematic species, at the RM1 site.

NATURAL ATTENUATION OF AQUEOUS METAL CONTAMINATION BY AN ALGAL MAT
Lawrence, J.R.; G.D. Swerhone; Y.T. Kwong
Canadian Journal of Microbiology, Vol 44 No 9, p 825-832, Sep 1998

A filamentous green algae was found forming an extensive mat below an outflow of acidic, metal-laden ground water at Macintosh Creek, MacMillan Pass, Yukon Territory, Canada. Emerging waters had a pH of 3.3. The concentrations of contaminants in waters that had coursed over the algal mat were typically reduced by between 5- and 10-fold. The concentration of dissolved arsenic declined from 32.9 to 9.3 micrograms/L(-1). Scanning electron microscopy (SEM) indicated that individual filaments of the algae were encrusted with mineral precipitate. The coatings were predominantly composed of Fe with other metals in the presence of S and P. Although culturing methods indicated the presence of 104-106 Thiobacillus ferrooxidans in the water, the microbes were not associated with the algal filaments. Hydrated samples were observed using a variety of methods. The algal filaments had an extensive exopolysaccharide surrounding the filaments, and mineralization occurred within the matrix, suggesting that factors such as the Eh and pH proximal to the algae might play an important role in mineral production.

NEUTRALIZATION OF SULFURIC ACID AND IMMOBILIZATION OF HEAVY METALS IN AN ACID ROCK DRAINAGE STREAM, EAST MANCOS RIVER, SAN JUAN NATIONAL FOREST, COLORADO
Meyer, W.A.; R.A. Parnell Jr.; J.B. Bennett
Geological Society of America, Abstracts with Programs, Vol 255, p 120, 30 Apr 1993

The East Mancos River of Southwestern Colorado is a stream naturally acidified by sulfuric acid produced by outcrops in its stream bed. In the headwaters of the river, two 20m dipslope exposures of fault breccias in the Entrada Sandstone are mineralized by pyrite, chalcopyrite, sphalerite, and galena. Over a 13.4 km distance downstream, solution chemistry rapidly changes and a sequence of inorganic then organic stream coatings are observed. To describe the natural geochemical processes controlling acid anion and heavy metal concentrations in the river, five longitudinal profiles were completed during 1991 and 1992. Complete inorganic chemical analyses of 0.1 μm filtered samples were performed. At each of the 16 water sampling stations, stream discharge was measured, and stream bed grab samples were collected for organic and inorganic characterization by optical petrography, x-ray diffraction, loss on ignition, and selective chemical dissolution. Sulfate, iron, aluminum, copper, zinc and hydrogen ion concentrations decrease steadily downstream. Moving downstream, the amount and composition of ferric oxyhydroxide precipitates decreases rapidly below the breccias. The co-existing iron phases include lepidocroicite, goethite, feroxyhyte, and ferrihydrite. At threshold stream compositions, epilithic coverings of bacteria and algae occur as iron precipitation ceases. Natural neutralization of sulfur acid and loss of heavy metals from solution occurs in excess of that expected by simple dilution of the initial acidic stream water. Abundances and compositions of stream bed precipitates are consistent with the observed losses of ions from the co-existing solution.

MANGANESE REMOVAL BY THE EPILITHIC MICROBIAL CONSORTIUM AT PINAL CREEK NEAR GLOBE, ARIZONA

Robbins, E.I.; T.L. Corley; M.H. Conklin

U.S. Geological Survey Toxic Substances Hydrology Program: Proceedings of the Technical Meeting, 8-12 March 1999, Charleston, South Carolina. Volume 1: Contamination From Hard-Rock Mining
U.S. Geological Survey Water-Resources Investigation Report 99-4018A, p 247-257, 1999

Interaction of an acidic mine drainage plume with subsurface material in an alluvial aquifer has released dissolved manganese [(Mn(II)] into the perennial reach of Pinal Creek near Globe, Arizona. A combination of hydrologic and biogeochemical precesses is responsible for precipitation of a fraction of the entering Mn(II) as Mn-oxyhydroxides on surficial sediments, within the streambed sediments, beneath algal mats formed on surficial sediments, and among mosses and emergent aquatic plants. This study focuses on the variety and seasonality of biological processes associated with Mn-oxyhydroxide precipitates formed on glass substrates placed in surface waters characterized by different flows and vegetation. The glass slides were emplaced monthly at a single subreach of Pinal Creek to assess epilithic attachment and Mn oxidation; epiphytic oxidation was assessed periodically
also. Oxidized Mn was associated with almost every organism in the consortium at Pinal Creek, from the microscopic to the macroscopic. Epilithic bacteria, fungi, algae, and protozoans were coated with oxidized Mn; every macrophyte examined had patches of oxidized Mn. The dominant epilithic precipitation forms were around holdfasts and within secreted substances. The black holdfasts of the iron bacterium, Leptothrix discophora, and the green alga, Ulothrix sp., were doughnut-shaped forms. Expansive patches of black extracellular polysaccharides were secreted primarily by bacterial filaments and fungal hyphae. The dominant macrophytic precipitation form was clumps of oxidized Mn on
mosses, green algae, and cyanobacteria. These clumps are consistent with Mn precipitation by elevated pH during photosynthesis. More Mn-oxide precipitates were found in the spring and summer months than the fall and winter, consistent with biological and chemical activity models, and more formed in swifter water than in slower moving water, consistent with oxygen elevation models. These findings provide a better understanding of the biological factors that influence natural attenuation of Mn at Pinal Creek and identify some of the complex interactions between biota, hydrologic processes, and water chemistry that need to be considered to fully assess the affects of acidic mine drainage on stream systems. More Info: http://toxics.usgs.gov/pubs/wri99-4018/Volume1/index.html

A CASE HISTORY OF INTRINSIC REMEDIATION OF REACTIVE TAILINGS SEEPAGE FOR QUESTA MINE, NEW MEXICO

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Intrinsic remediation is the effect of natural attenuation mechanisms—dilution, dispersion, sorption/precipitation and biodegradation—reducing contaminant concentrations in ground water to specified levels at predetermined compliance points in the aquifer. Current monitoring and modeling for post closure was used to assess the current and long-term potential of intrinsic remediation of contaminated seepage originating from a large reactive (sulfidic) tailings impoundment near Questa, NM. It is concluded that the natural attenuation mechanisms of precipitation within the tailings and dilution/dispersion within the aquifer are active and likely sufficient to reduce contaminant concentrations

to below state standards in the long-term. Sorption and biodegradation within the receiving aquifer(s) were not assessed.